INTRODUCTION

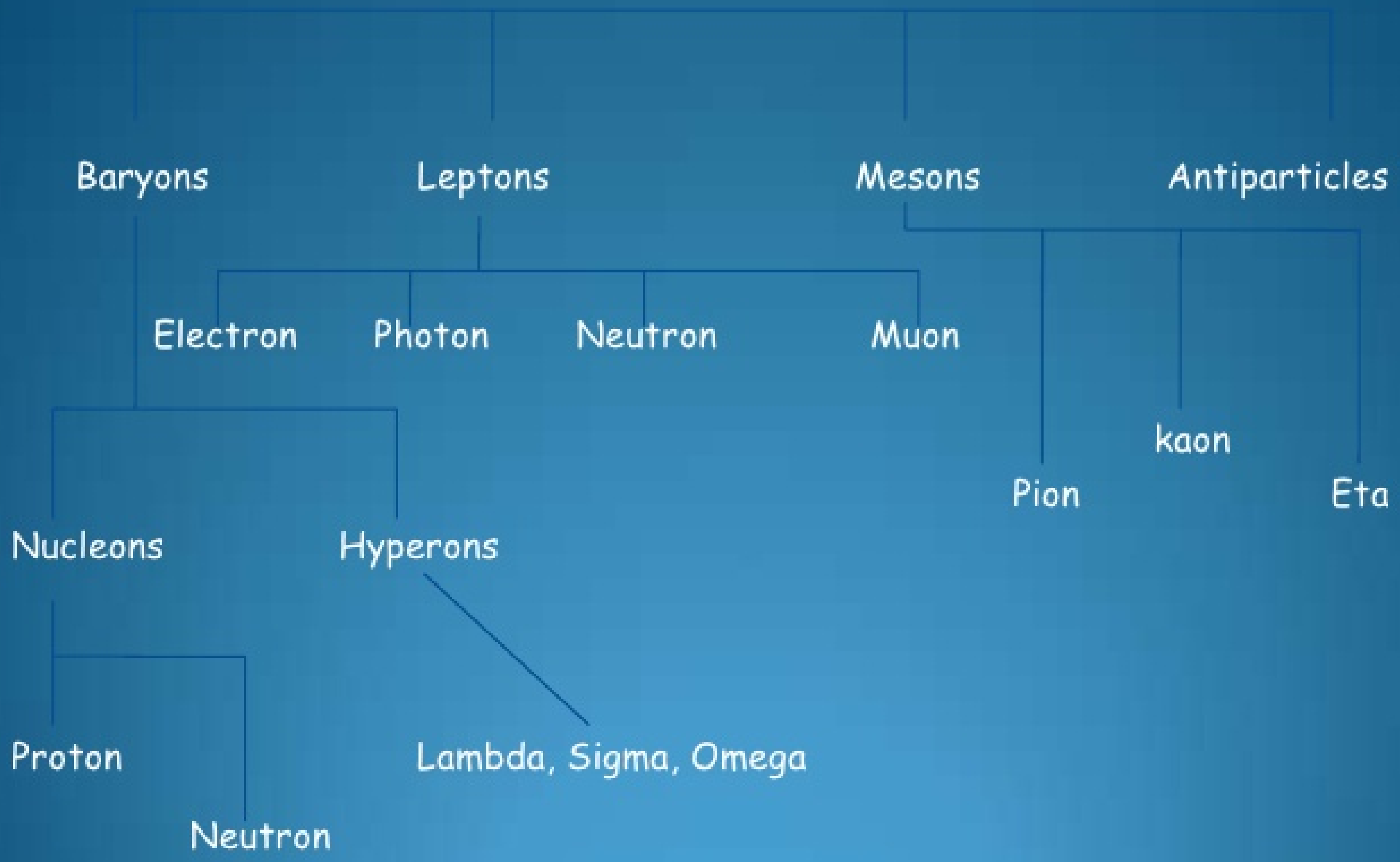
* By the year 1932, only three elementary particles namely electron, proton and photon were known.

* The discovery of Neutron by Chadwick in 1932 raised their number to four.

* These elementary particles are the building blocks of matter & they have characteristic properties such as rest mass, electric charge & intrinsic angular momentum.

* The elementary particles discovered so far, form a long list of around 200. These particles are elementary in the sense that they are structureless, i.e., they cannot be explained as a system of other elementary particles.

Elementary particle



	Name	Symbol	Charge	Spin	Rest Energy (MeV)
Leptons	Photon	γ	0	1	0
	Neutrino	ν_e	0	1/2	0
		ν_μ	0	1/2	0
	Electron	e^+, e^-	+1, -1	1/2	0.511004(2)
	Muon	μ^+, μ^-	+1, -1	1/2	105.659(2)
Mesons	Pion	π^+, π^-	+1, -1	0	139.576(11)
		π^o	0	0	134.972(12)
	Kaon	K^+, K^-	+1, -1	0	493.82(11)
		K^o	0	0	497.76(16)
	Eta	η^o	0	0	548.8(6)

	Name	Symbol	Charge	Spin	Rest Energy (MeV)
B A R Y O N S	Proton	P	1	1/2	938.256(5)
	Neutron	n	0	1/2	939.550(5)
	Lambda	Λ	0	1/2	1115.60(8)
	Sigma	Σ^+	+1	1/2	1189.4(2)
		Σ^0	0	1/2	1192.46(12)
		Σ^-	-1	1/2	1197.32(11)
	X_i	Ξ^0	0	1/2	1314.7(7)
		Ξ^-	-1	1/2	1321.25(18)
	Omega	Ω^-	-1	3/2	1672.5(5)

PHOTON

* no charge & no rest mass
* It has energy given by Plank's equation E=hν
* It has an equivalent mass given by Einstein's equation $E=mc^2$.

NEUTRINO

* 1956 – Beta ray spectra in radioactivity
* no charge & rest mass is zero
* It travels with the speed of light
* It exists in two form, one associated with electron & the other with the muon

HYPERONS

* Time decay of the order of 10^{-10} seconds

* Mass value intermediate between neutron & deuteron

* Their decay time is very much greater than the time of their formation (10^{-3} sec).

* K mesons – Strange Particles (Gellmann & Nishijima)

* Four types – Lambda, Sigma, Xi, Omega

BARYONS (Or) heavy particles

* Protons & particles heavier than proton form this group.

* Proton and neutron are called nucleons and the rest mass are called hyperons.

* Every baryons has an antiparticle.

* If a number, called the baryon number +1 is assigned to baryons and a number -1 is assigned to antibaryons, then in any closed system interaction or decay, the baryon number does not change. This is the law of conservation of baryons.

Neutrino and Antineutrino

- It has Charge Zero, spin ½, zero rest mass and magnetic moment smaller than 10^{-8} Bohr magneton or nearly zero.
- Finite energy, momentum and travels with the speed of light. It does not cause ionization on passing through matter.
- The spin of the neutrino is opposite in direction to the direction of its motion. (neutrino spins – counterclockwise)
- The spin of the antineutrino is in the same direction as its direction of motion. (It spins clockwise)
- The neutrino moves through space in the manner of a left-handed screw, while the antineutrino does so in the manner of a right-handed screw.

Continue...

Neutron and Antineutron

Discovered in 1956 by Cork, Lamberton and Wenzel.

The nature of antineutron is not very well known.

Both have zero charge and the same mass.

Antineutron is quickly annihilated, either by a proton or a neutron, usually with the production of several pions.

If an antineutron is not annihilated by a nucleon, it decays by the reaction $n^{-} \rightarrow P^{-} + \beta^{+} + \nu$

Leptons

* It contains electron, photon, neutrino & muon.

* All these elementary particles have masses smaller than that of a pion.

ELECTRON

* First discovered particle

* negative charge & stable particle

* An electrostatic field exists between two electrons

Positive Pimeson (Pion)

- Mass equal to 273 times the mass of the electron.
- positively charged particle & life time - 10^{-8} sec

Neutral Pion

- No charge
- Mass is equal to 264 times the mass of the electron

Charged Kaon: +ve charge & a mass of about one-half of proton.

Neutral kaon: No charge & Its life is of the order of 10^{-9} sec

Proton and antiproton

Dirac's theory, anticipating the positron, could be interpreted as implying a particle identical to the proton, except for a negative charge.

Antiprotons were produced by bombarding protons in a target with 6 GeV protons.

$$P + P(+\text{energy}) \rightarrow P + P + P + P^-$$

Antiprotons interact strongly with matter and annihilate with protons.

$$P + P^- \rightarrow \pi^+ + \pi^- + \pi^+ + \pi^- + \pi^o$$

MESONS

* Masses are between those of leptons & baryons.

* They are unstable.

* They decay into lighter mesons or leptons.

* They have either positive, negative at zero charge.

* The mesons include the pion, kaon and eta particles.

PARTICLES & ANTI-PARTICLES

Electron – Positron

* Same mass & the same spin but opposite charge

*They annihilate each other with the emission of photons

* The existence of an antiparticle for the electron was actually predicted by Dirac, because of a symmetry of the equations of the relativistic quantum theory of the electron.

- Positron was discovered by Anderson in 1932.

- Neutrino possesses a “left-handed” helicity ; the antineutrino possesses a “right-handed” helicity.
- Neutrino’s emitted in Beta decay have a negative helicity.
- They are longitudinally polarized with their spin axes antiparallel to their direction of travel.
- H = + 1 for ν^{-} ; H = - for ν
- Because of its lack of charge and magnetic moment, a neutrino has essentially no interaction with matter, except that which leads to inverse beta decay. This interaction is extremely weak. ($\sigma \approx 10^{-20}$ barn)
- Matter is almost totally transparent to neutrinos.

Conservation of Parity

- Parity relates to the symmetry of the wave function that represents the system.
- If the wave function is unchanged then the system has a parity of +1. If changed, then the system has parity of -1.
- During a reaction in which parity is conserved, the total parity number does not change.
- Prior to 1956 it was believed that all reactions in nature obeyed the law of conservation of parity.
- Yang and Lee pointed out that in reactions involving the weak interaction, parity was not conserved.
- Indeed parity conservation is found to hold true only in the strong and em interactions.

Charge conjugate symmetry

- It is the act of symmetry operation in which every particle in a system is replaced by its antiparticle.

- If the anti-system or antimatter counterpart exhibits the same physical phenomena, then charge parity (C) is conserved.

- In fact C is not conserved in the weak interaction.

Time reversal symmetry

- Time parity T describes the behaviour of a wave function when t is replaced by –t.
- The symmetry operation that corresponds to the conservation of time parity is time reversal.
- The direction of time is not significant, so that the reverse of any process that can occur is also a process that can occur.
- Prior to 1964, time parity T was considered to be conserved in every interaction.
- One form of K^0 kaon can decay in to π^+, π^-, which violates the conservation of T.
- The symmetry of phenomena under time reversal does not seem to be universal.

Combined Inversion of CPT

- The combined symmetry operation in which the antimatter mirror-image of a system is run in reverse allows a test of CPT invariance.
- The conservation of CPT means that for every process there is an antimatter mirror-image counterpart that takes place in reverse.
- This particular symmetry seems to hold for all interactions, even though its component symmetries sometimes fail individually.

Muon

* It is similar to the electron except that its mass is about 200 times that of the electron.
* It decays very quickly with a half life of 2.2μs into one electron and two neutrinos.
* It is negatively charged and has a spin of ½.
* It was first discovered during the study of cosmic rays.

1. Introduction

2. Classification

3. Particles & Antiparticles

4. Particles instability

5. Conservation laws